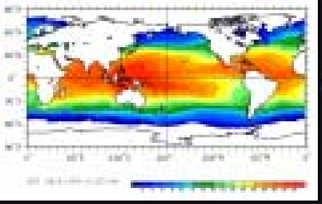

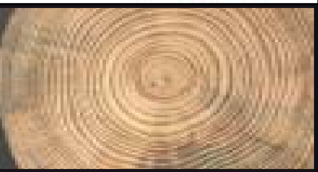

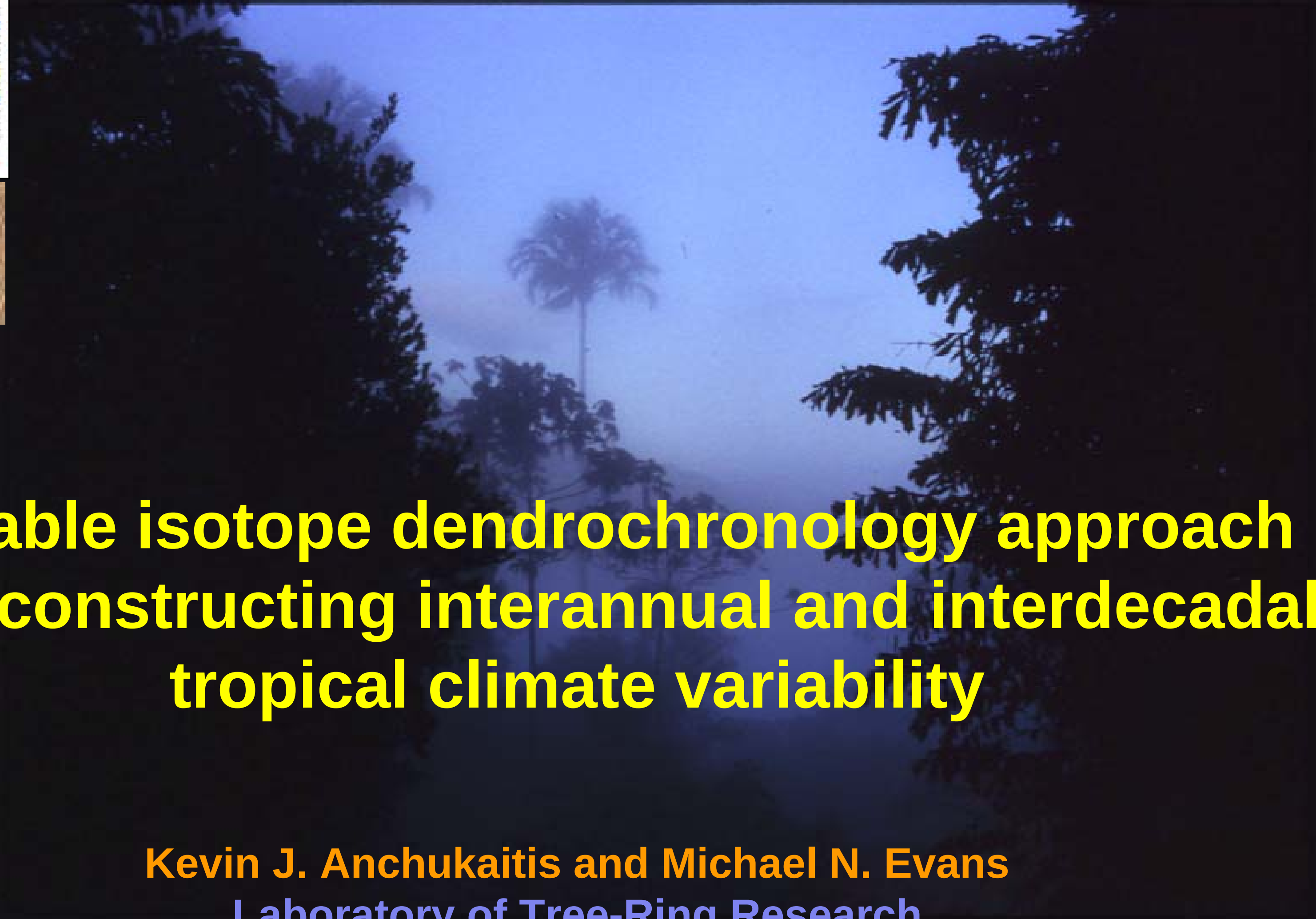

A stable isotope dendrochronology approach to reconstructing interannual and interdecadal tropical climate variability

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The University of Arizona, Department of Geosciences

Evans, M.N. and D.P. Schrag, 2004: **A stable isotope-based approach to tropical dendroclimatology**, *Geochimica et Cosmochimica Acta*, 68(16), 3295-3305

Poussart, P.F., M.N. Evans and D.P. Schrag, 2004, **Resolving seasonality in tropical trees: multi-decade, high-resolution oxygen and carbon isotopic records from Indonesia and Thailand**, *Earth and Planetary Science Letters*, 218, 301-316

Summary

- ***Challenges and Possibilities for Tropical Dendrochronology***

- ***Progress in tropical isotope dendroclimatology***

- ***"Paradoxical Dendrochronology" – Using Tropical Montane Cloud Forests for Paleoclimatology***

- ***Theoretical and Technical Considerations for Tropical Dendrochronology in Neotropical Cloud Forests***

Introduction

Do The Tropics Rule? *(Cane and Evans 2000)*

ENSO is dominant mode of interannual climate variability

- *Tropics have the energy and dynamics to influence global climate*

- *Tropical interannual and interdecadal variability cause anomalous climate patterns around the world through atmospheric teleconnections*

✓ *Unfortunately*, long instrumental weather records are sparse in the tropics; increased proxy records from the tropics needed

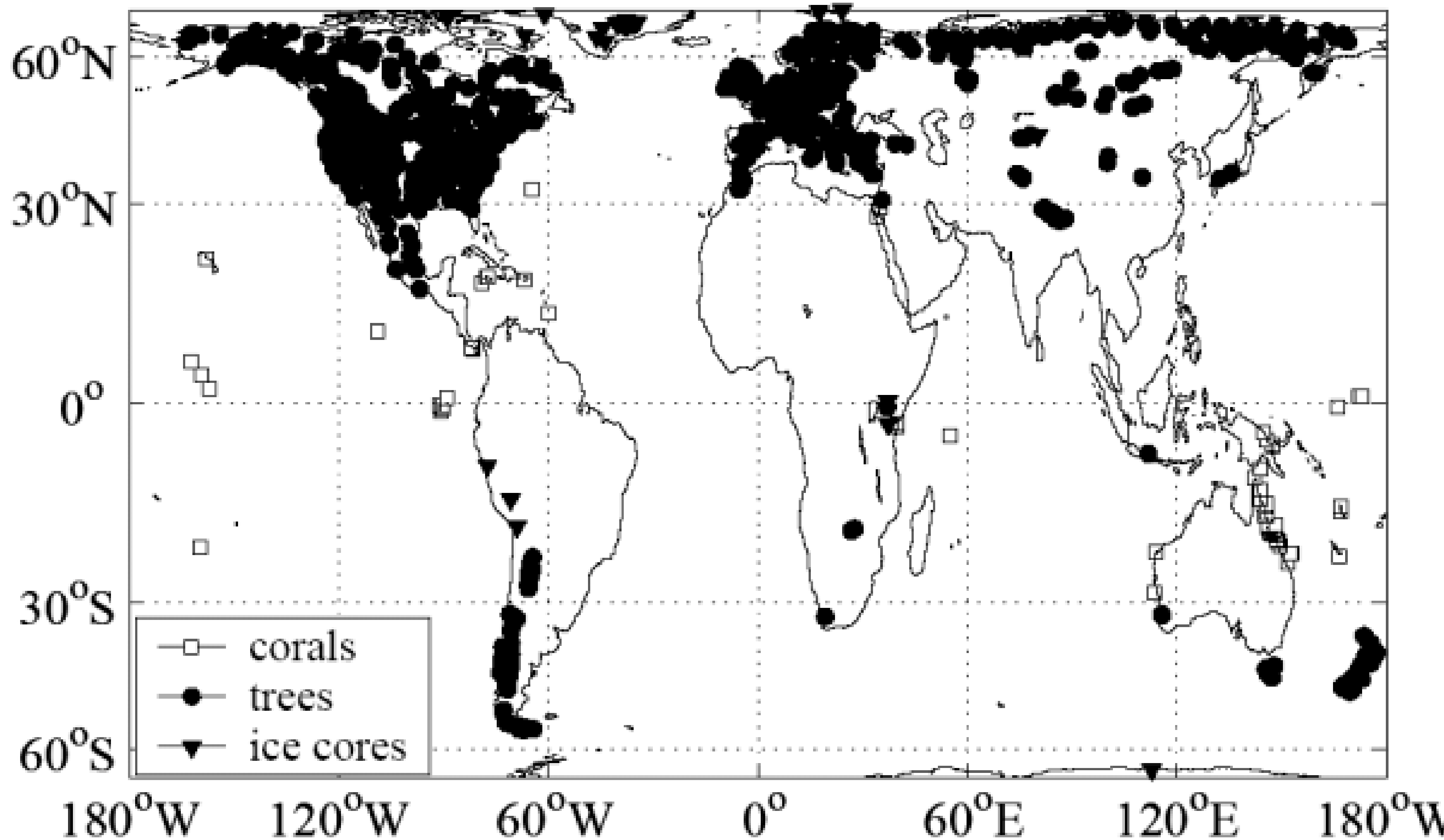


Fig. 1. Equal-area map of locations of high resolution coral and tree-ring paleoclimate data currently in the NGDC World Data Center-A for Paleoclimatology electronic database (http://www.ngdc.noaa.gov/paleo/). Plots as of June 2003.

Evans and Schrag [2004]

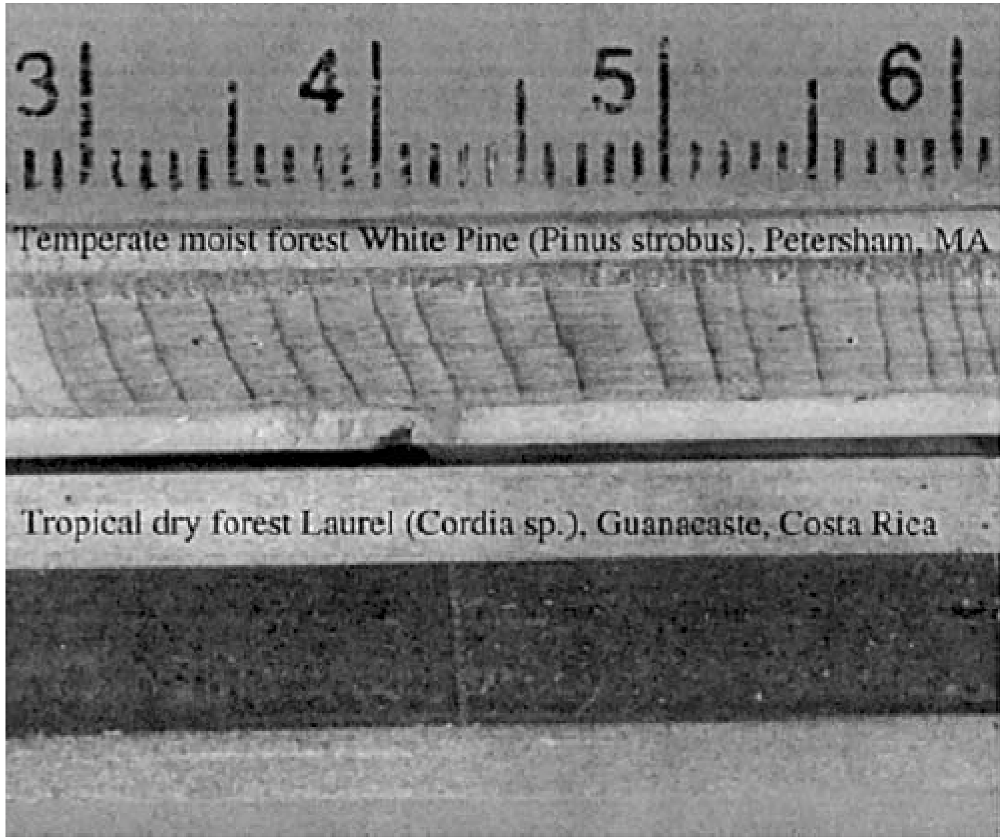
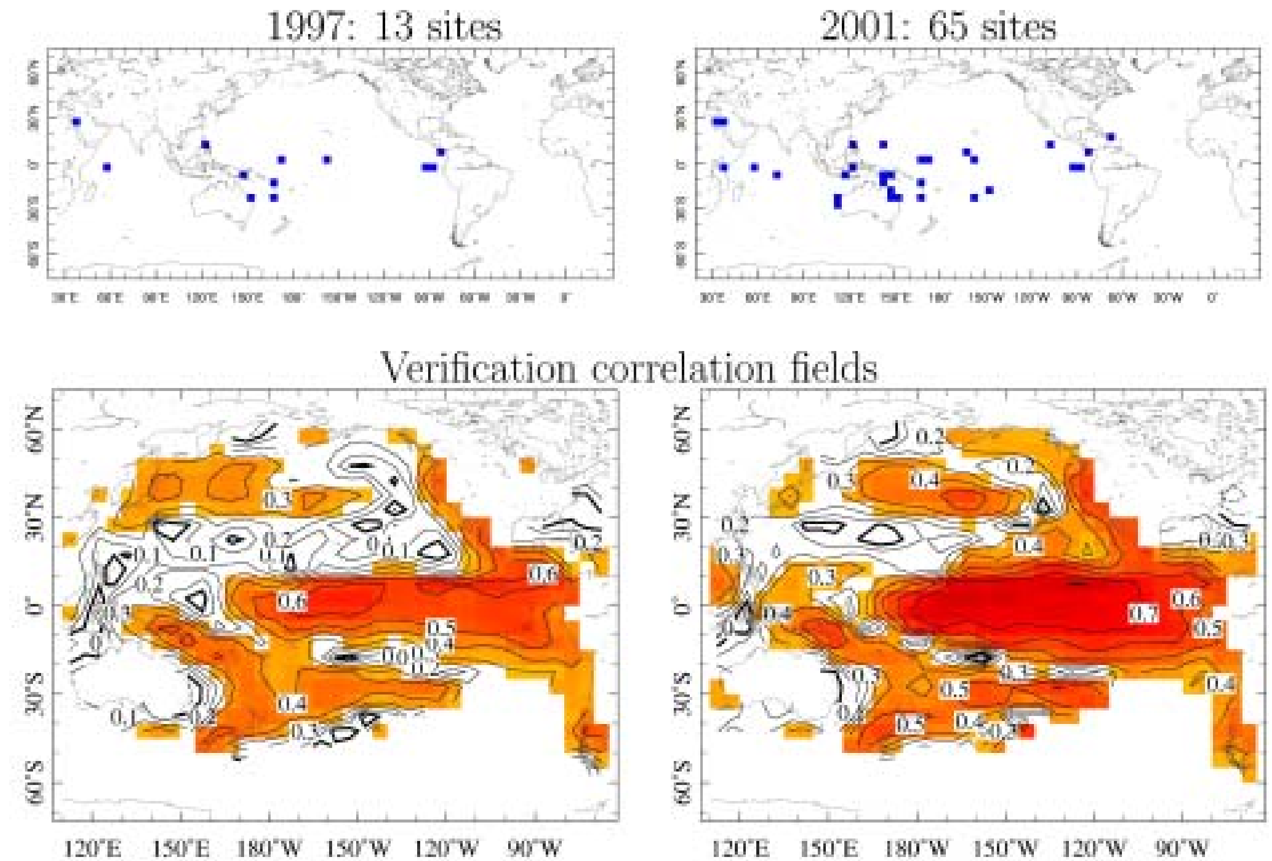


Fig. 2. Photographs of 5 mm-diameter increment core sections taken from extratropical and tropical tree species. Top: Harvard Forest (Petersham, MA, USA) Pinus strobus (White Pine). Bottom: Costa Rican dry forest Cordia sp. (Laurel). The scale is in centimeters. Both cores are mounted onto blond wood core-holders. Rings are clearly visible in the P. strobus core, but the Costa Rican Cordia sp. is a uniform, dark color throughout.

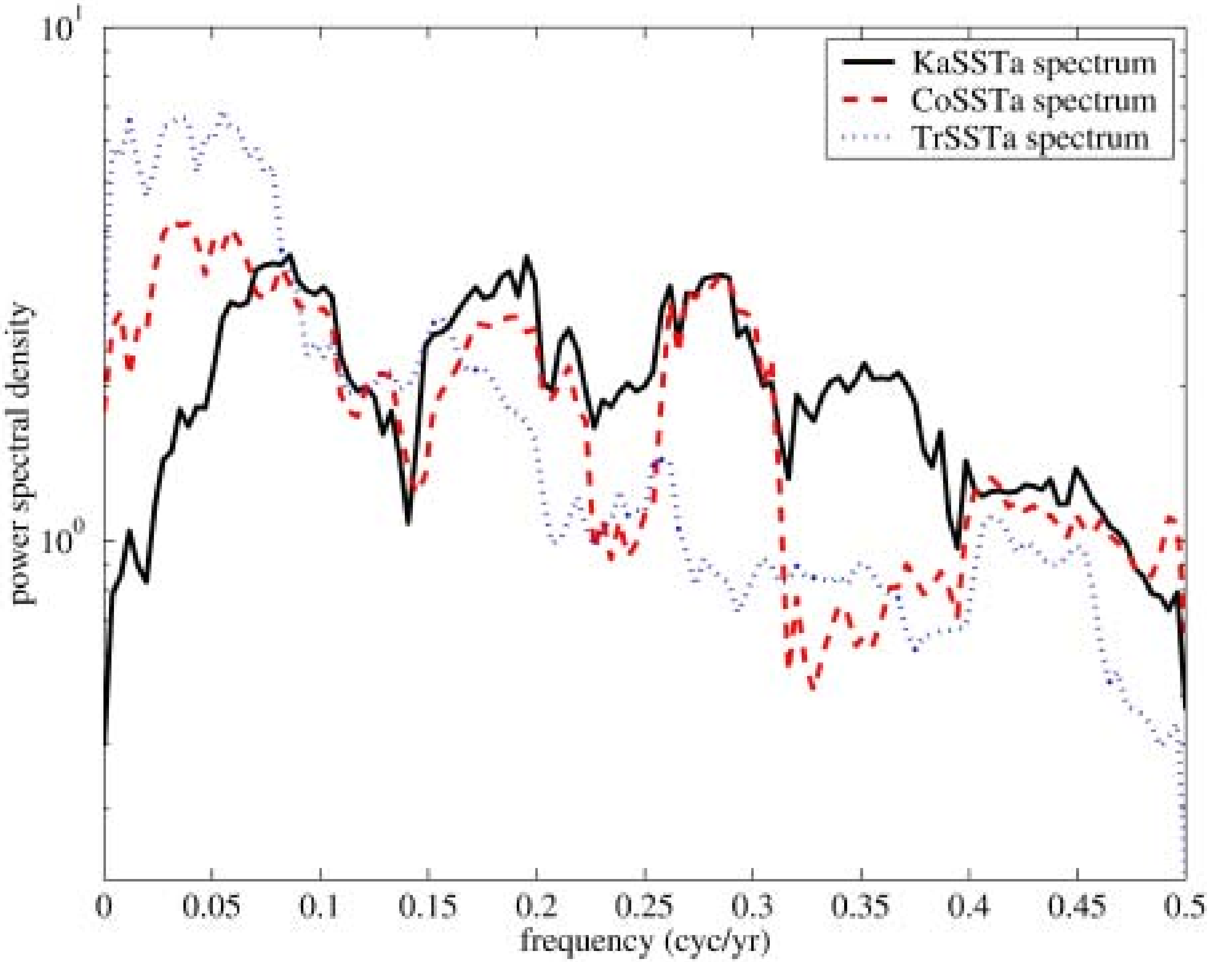
Evans and Schrag [2004]

Proxy network (corals) SST field reconstruction: More data is better.



Evans et al. [2002]

Will the true decadal power spectrum please stand up?



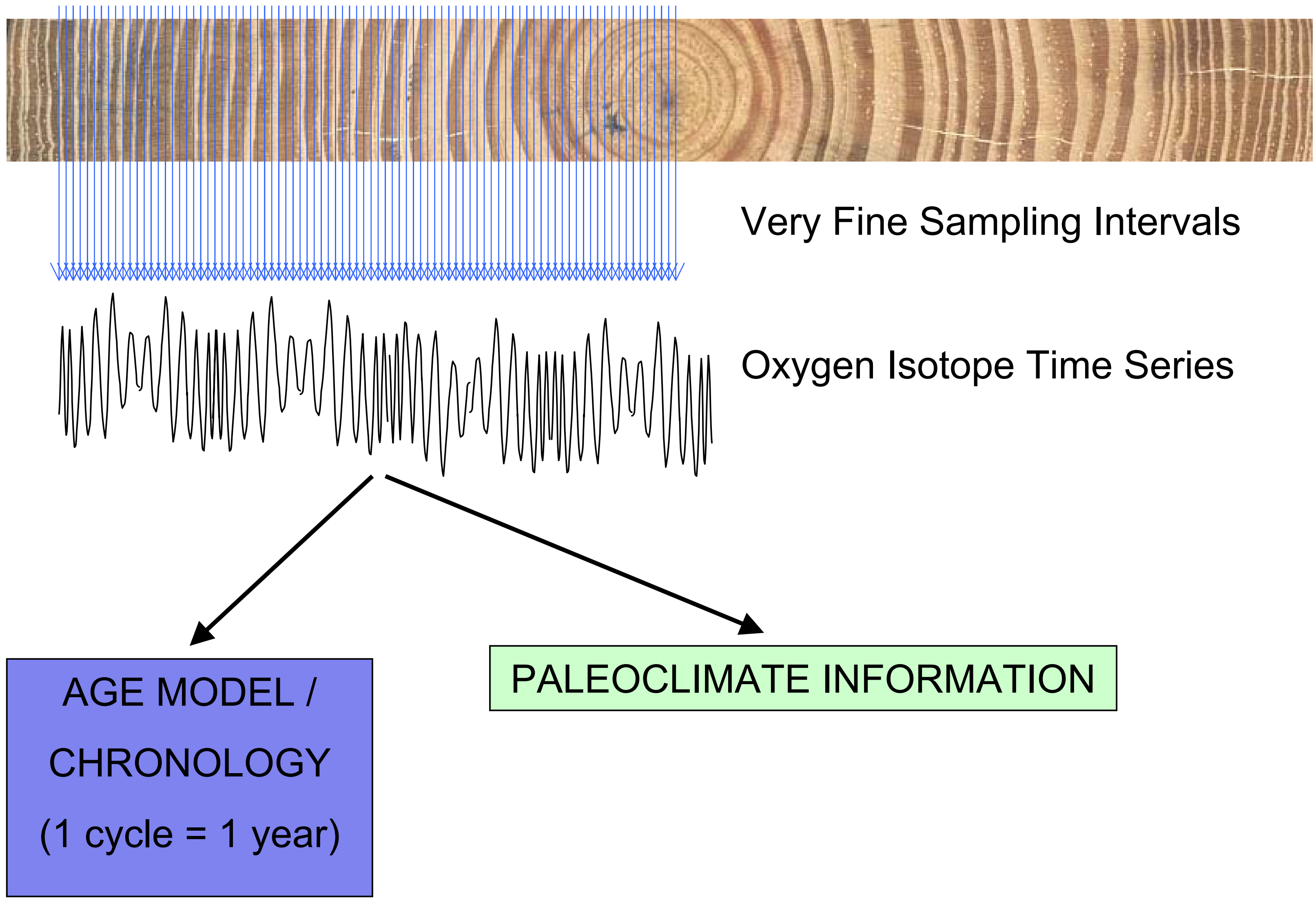
Evans et al. [2002]

Tropical isotope dendrochronology

“[Establish] a strategy to develop chronometric estimates in tropical trees lacking demonstrably annual ring structure, using high resolution stable isotopic measurements in tropical woods.”

Evans and Schrag [2004]

methodology



technology

1. Mechanistic Model

[Roden *et al.* 2000]

$$\delta^{18}O_{\text{cellulose}} = f_O \cdot (\delta^{18}O_{\text{wx}} + \varepsilon_O) + (1 - f_O) \cdot (\delta^{18}O_{\text{wl}} + \varepsilon_O)$$

2. Continuous flow IRMS

[Brenna *et al.* 1999]

- Oxygen isotope composition of organic matter
- throughput: one 100ug sample / 5 minutes
- Precision approaching 0.3 ‰ on standard materials

3. Alpha-cellulose processing chemistry

[modified after Brendel *et al.* 2000]

- Non-toxic, easy, cheap
- Fast: 100 samples/person/4 hours

Stable Isotope Model

Roden *et al.* (*2000*) Oxygen Isotope Model

$$\delta^{18}O_{cellulose} = \boxed{f_O} \cdot \boxed{(\delta^{18}O_{wx} + \varepsilon_O)} + \boxed{(1 - f_O)} \cdot \boxed{(\delta^{18}O_{wl} + \varepsilon_O)}$$

Fraction of xylem water that does not experience evaporative enrichment in the leaves

Oxygen isotope ratio of xylem water plus biological fractionation

Fraction of plant water that undergoes evaporative enrichment in the leaves

Oxygen isotope ratio of leaf water plus biological fractionation

✓ Most important controls on cellulose oxygen isotope values are source water isotope ratios and the amount of leaf water that experiences evapotranspiration (a function of relative humidity, insolation).

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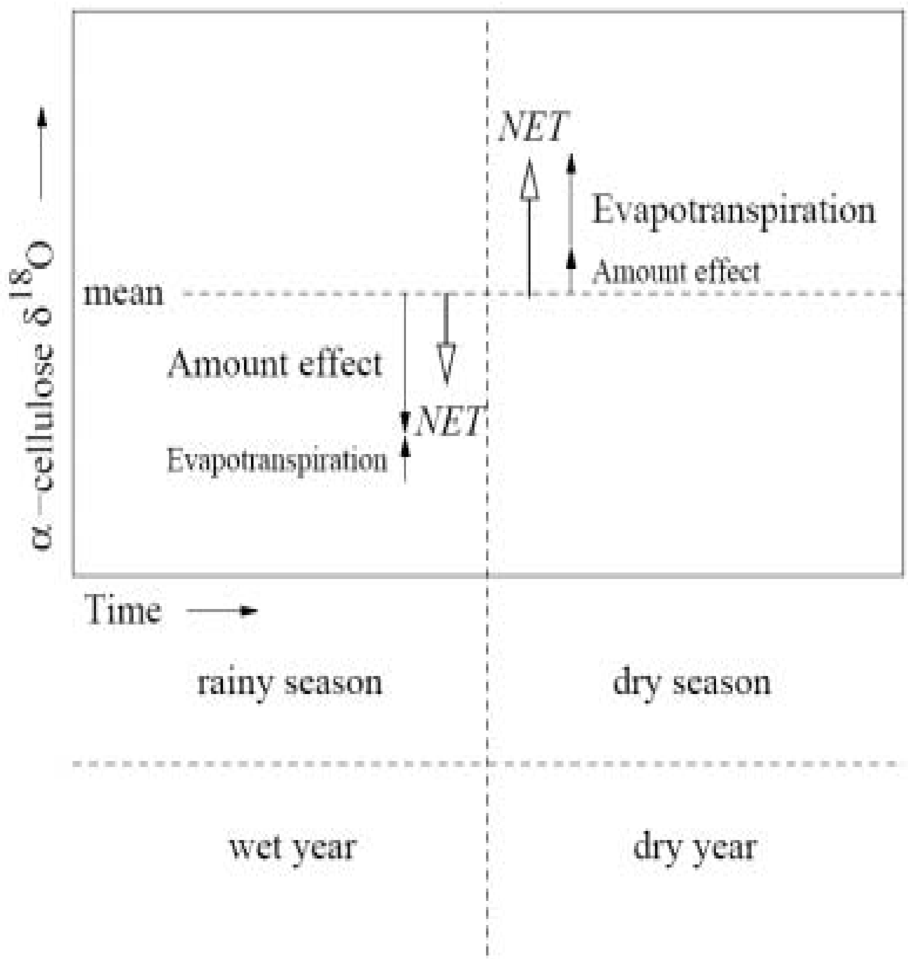
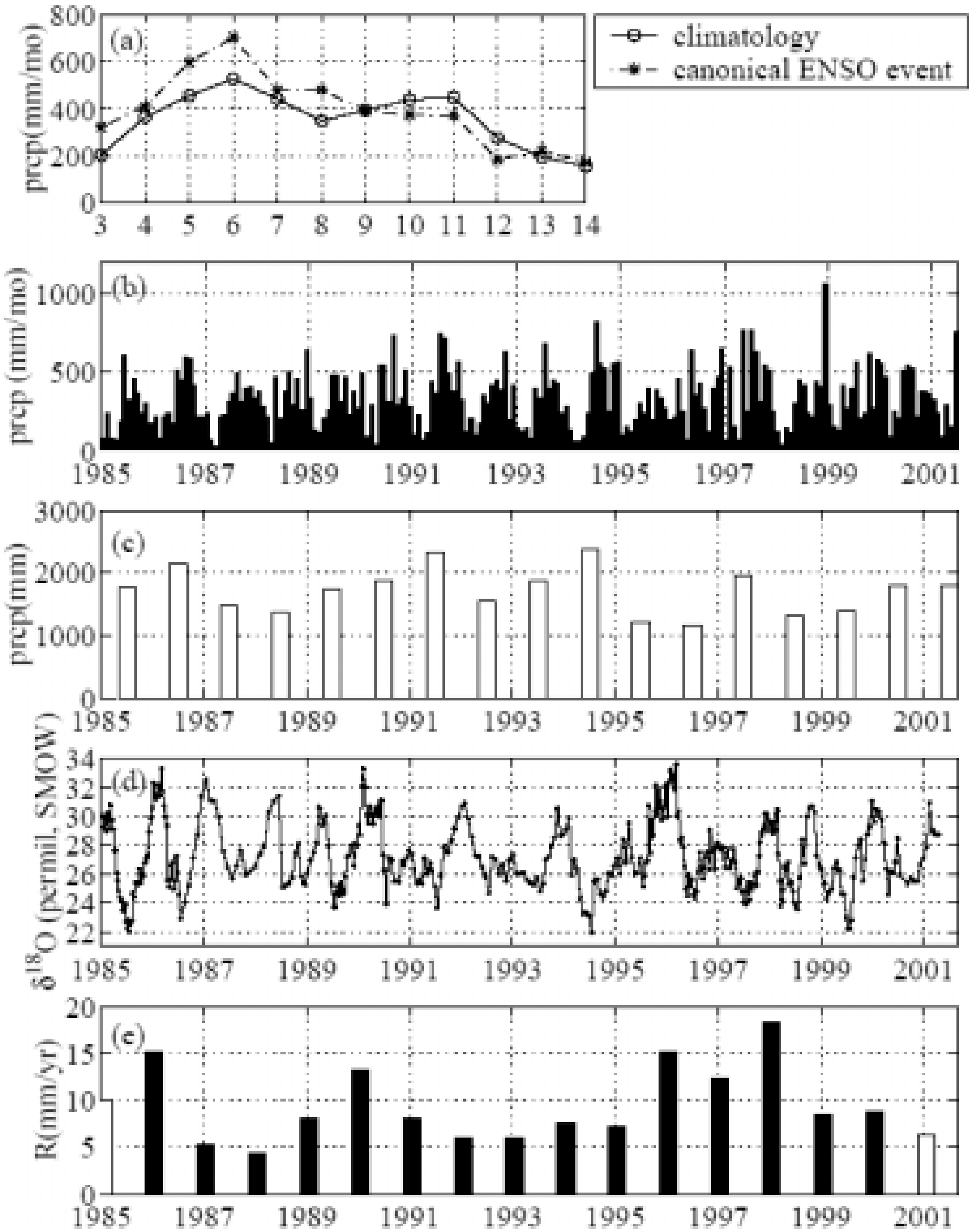
Chronology from isotopes



Evans and Schrag [2004]

- During the rainy season the amount effect in tropical convective rainfall should dominate over weaker leaf evaporation, leading to lower xylem $\delta^{18}O$ values.
- During the dry season, leaf evaporation will dominate over the amount effect, leading to higher xylem $\delta^{18}O$ values.
- Analogous situation in dry vs. wet years.

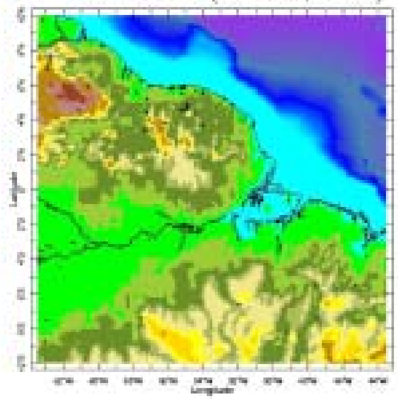


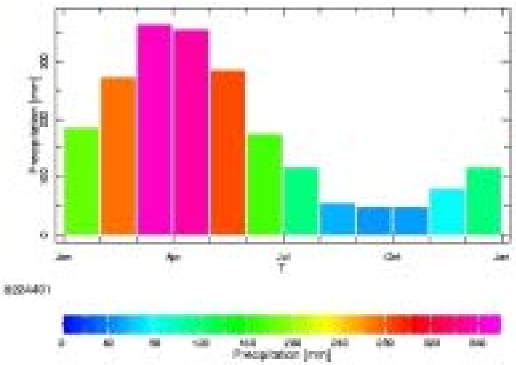
Evans and Schrag [2004]

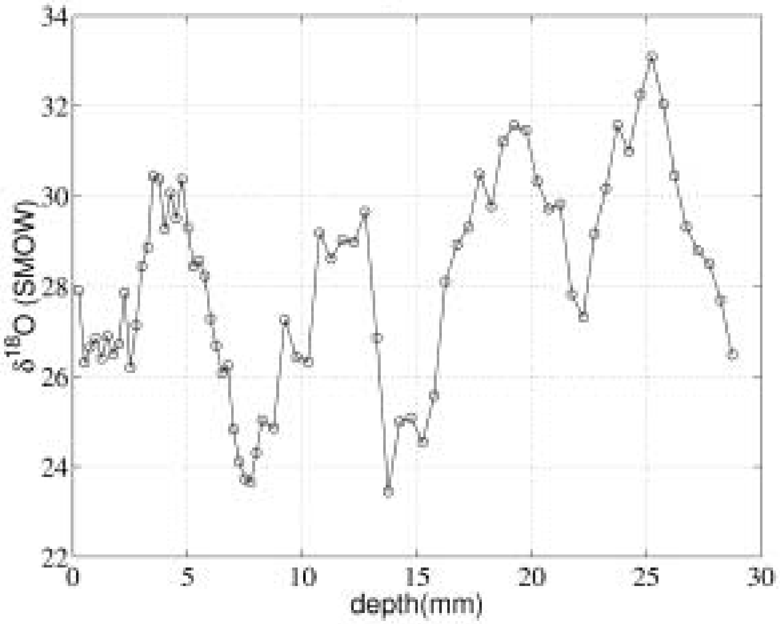
Hyeronima alchorneoides
La Selva, Costa Rica
(tropical wet forest)

- 17±2 isotope cycles for 17 year-old trees. 4-6 ‰ cycles in the series at intervals ranging from 4-18mm.
- The highest JJAS rainfall totals are found in 1994, 1991, 1986, and 1997, and correspond to low $\delta^{18}O$ values.
- A wet period from 1990–1991, corresponds to a damped annual cycle and lower 1990–1991, a wet period, corresponds to a muted annual cycle and low $\delta^{18}O$ values, and is consistent with a rainy dry season in winter 1990-1991.

Results: Amazon Rain Forest *Erisma uncinatum*

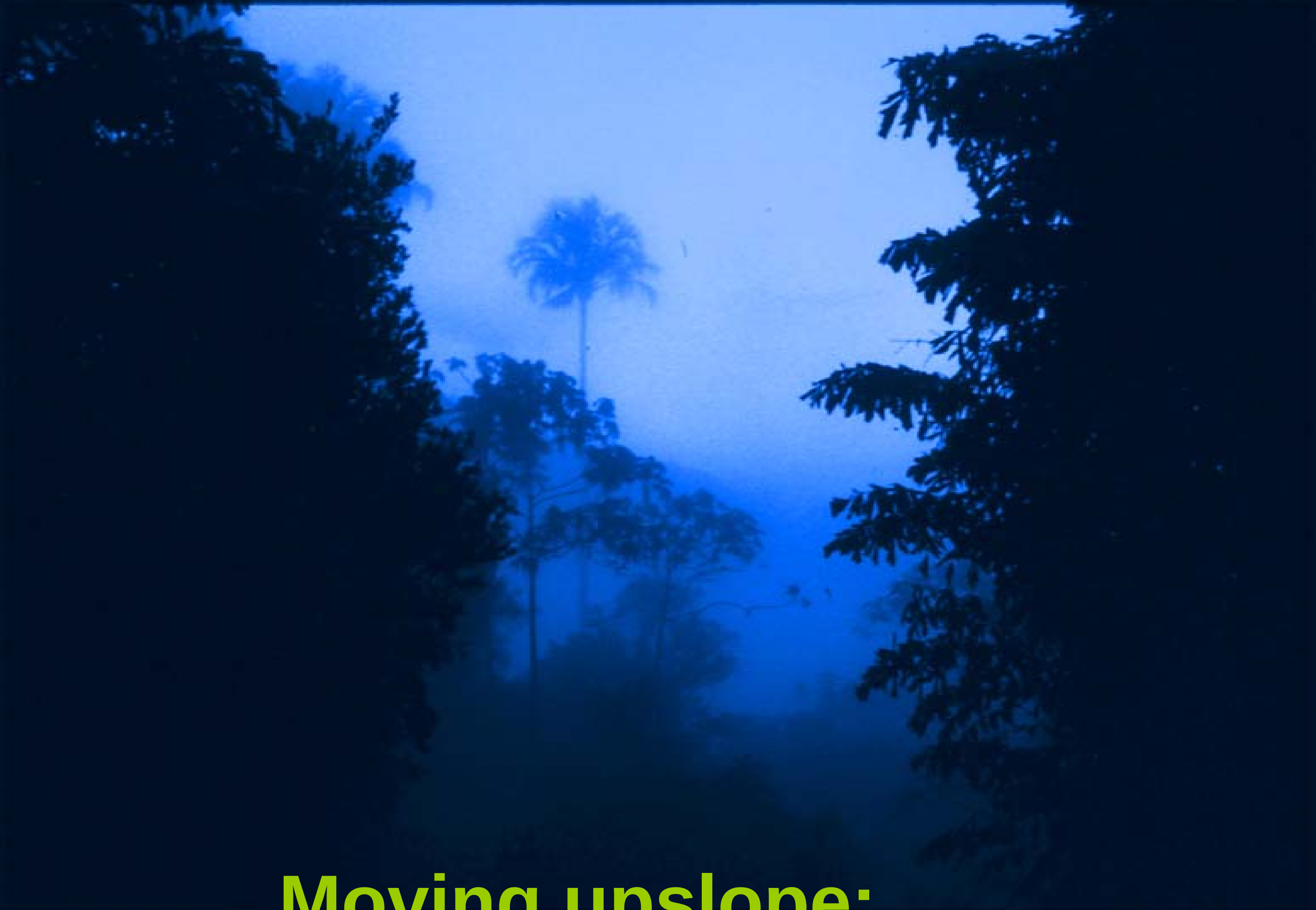






- Growth rates in most recent year (5-9mm/yr) consistent with radial growth measurement (5mm/yr) made in year prior to sampling.

Evans et al. [2002]



Moving upslope:

a tropical isotope dendrochronology approach to neotropical montane cloud forest paleoclimatology

Objective

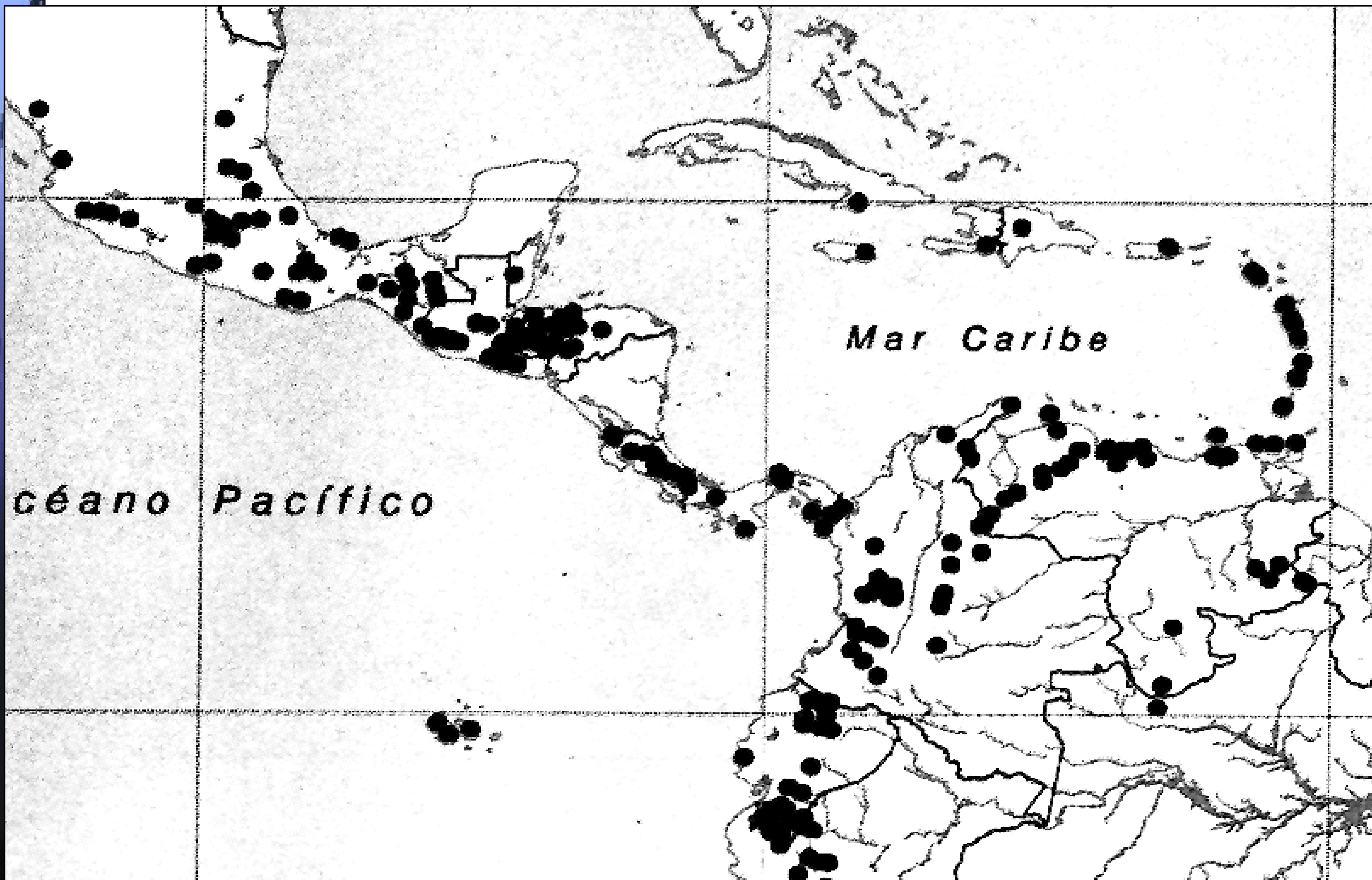
*Use **stable isotope dendrochronology** and the **unique hydroclimatic conditions of tropical montane cloud forests** to construct a proxy record of Pacific climate variability from the terrestrial tropics.*

- *Takes advantage of "**isotopic seasonality**" of cloud forest hydrology for telling time AND reconstructing climate*

- ***Doesn't*** **require** ***annual rings***

Neotropical cloud forests

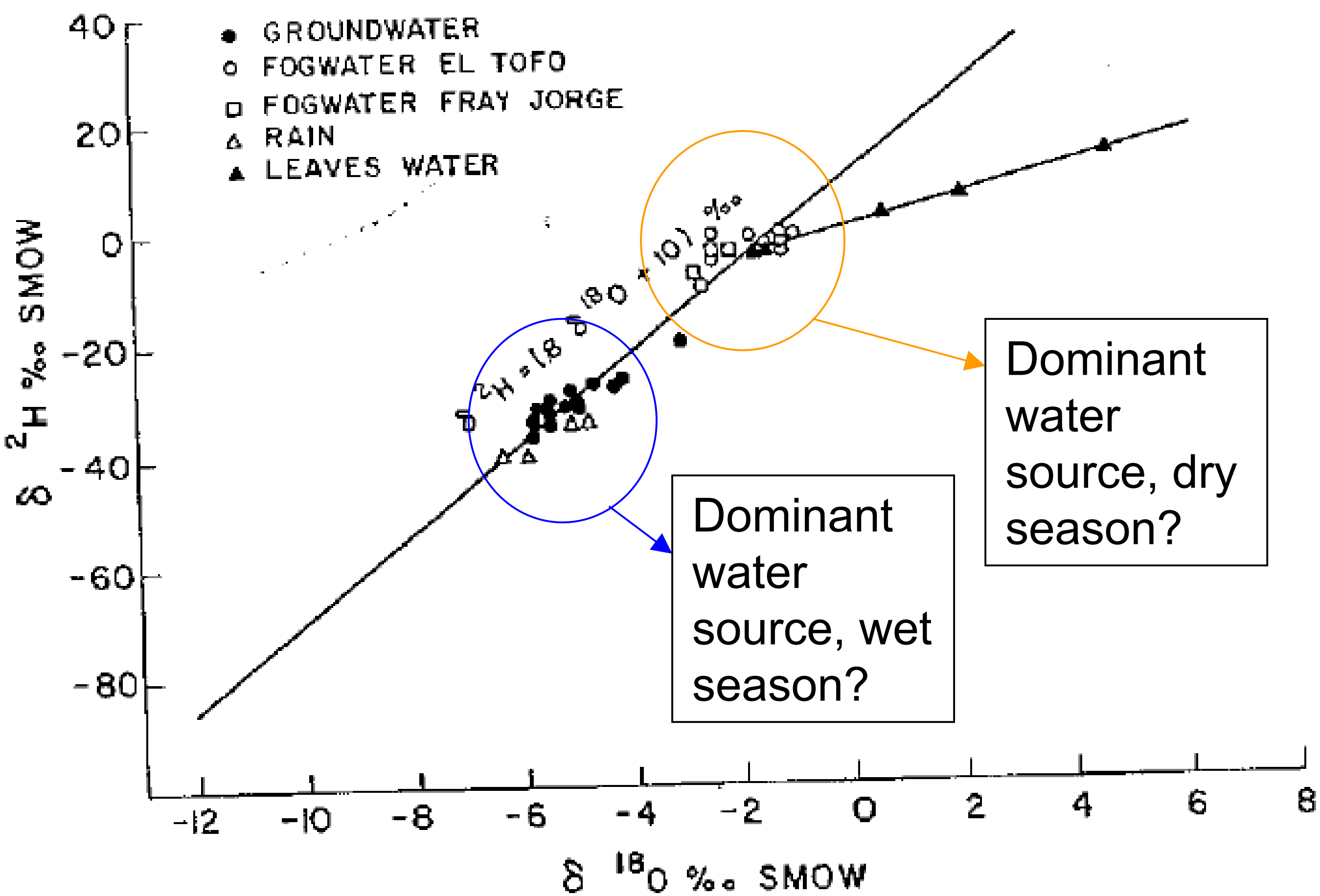
Neotropical Montane Cloud Forest Locations



Source: Kappelle and Brown 2001

“isotopic seasonality”

Why Cloud Forests?
Rainfall vs. Fog Water Isotope Values



Source: Aravena et al. 1989

Theoretical Background

3 CORE ASSUMPTIONS:

[1] Oxygen isotope ratio of tree cellulose records the changes in climate and weather (seasonal and interannual),

[2] Cloud forest trees use different sources of water with distinct oxygen isotope signatures over the course of the year

[3] Sea surface temperature changes will alter atmospheric conditions and water use in cloud forests sufficiently so as to be detected in the oxygen isotope ratio of tree cellulose.

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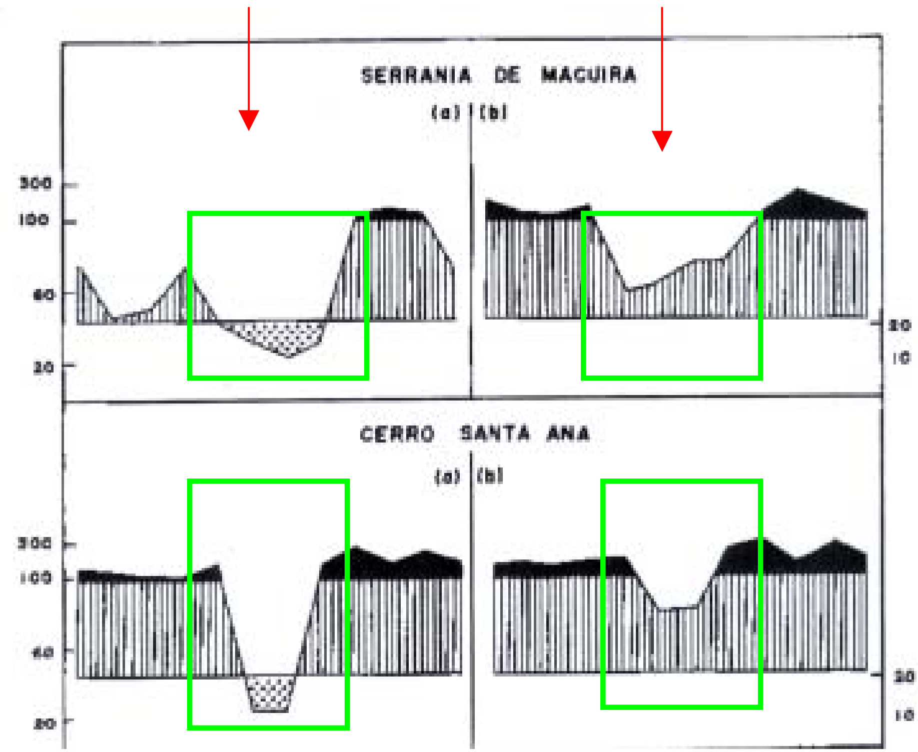
Hydroclimatology

RAINFALL ONLY

RAINFALL + CLOUD INPUTS



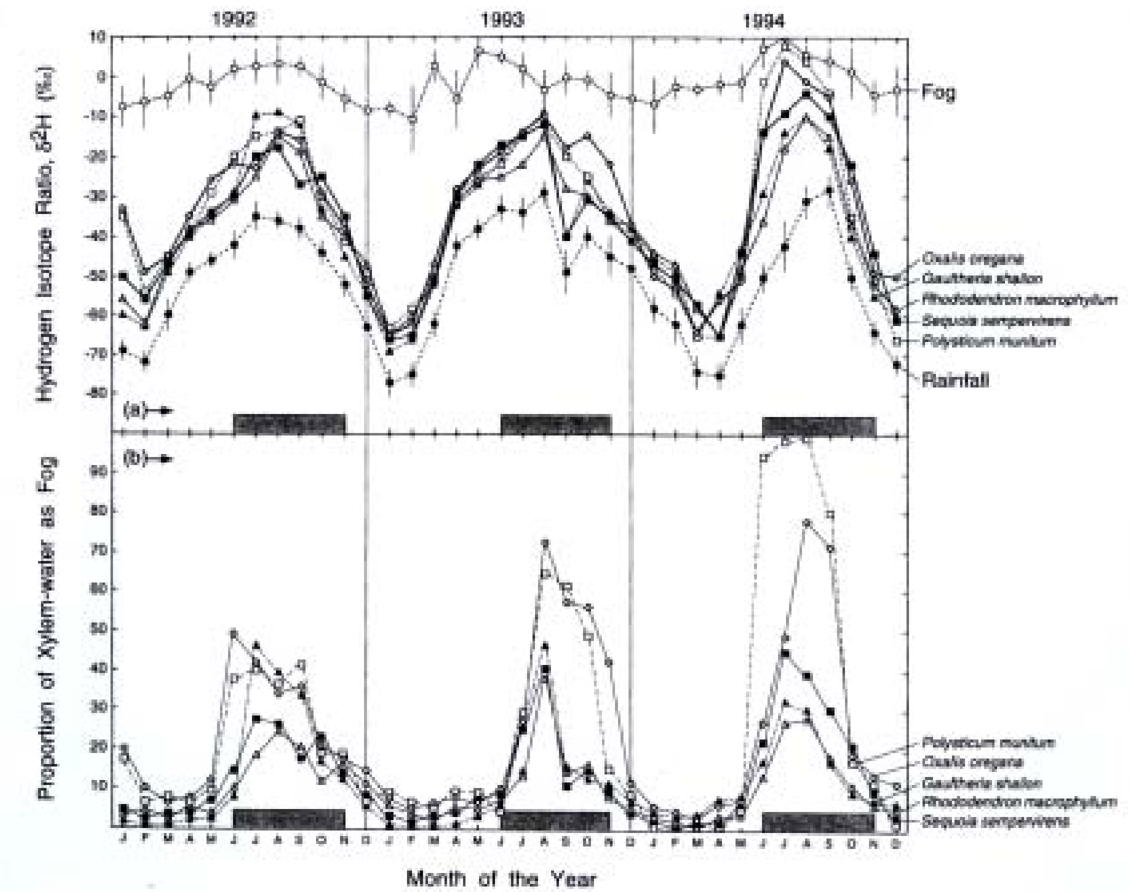
✓Cloud water inputs to montane forests compensate for lack of rainfall during regional dry season.

Figure from Cavalier and Goldstein 1989

tree-water relationships

Precipitation vs. Fog Water Use in
Sequoia-dominated ecosystems

Source: Dawson 1998



✓ Trees in "fog-dependent" ecosystems with wet-dry seasonality rely on cloud-water inputs during the "dry" season and precipitation during the rainy season.

Theoretical Background

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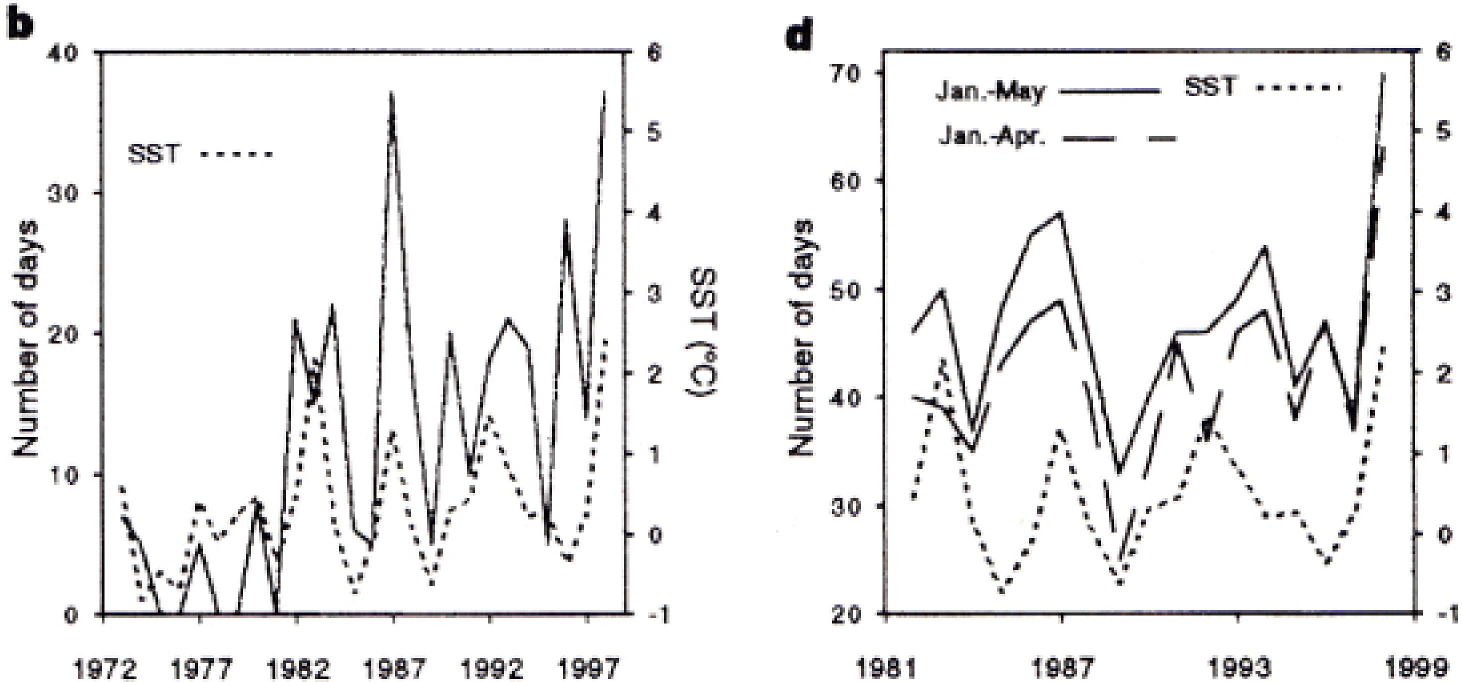
interannual variability

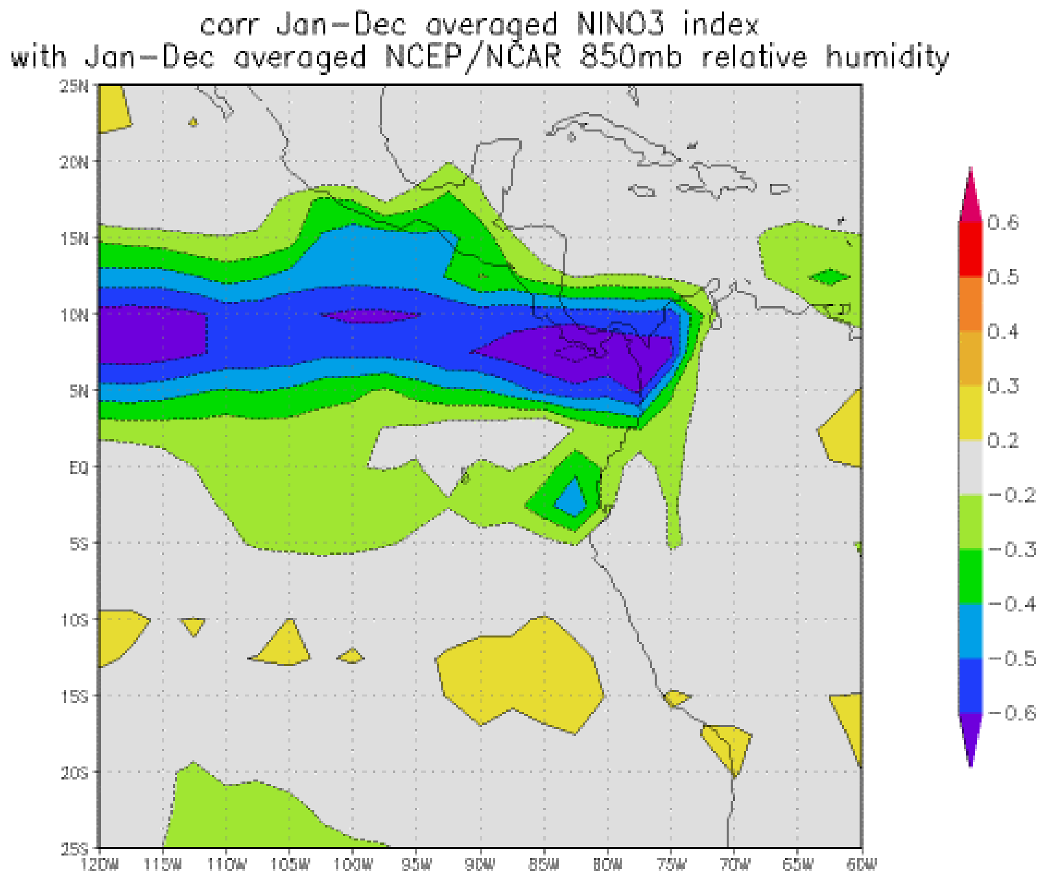
Clear-Sky Days at Monteverde



✓ There are more dry days in the Monteverde Cloud Forest in Costa Rica when eastern Pacific Sea Surface Temperatures are higher ($p<0.05$)

Source: Pounds et al. [1999]

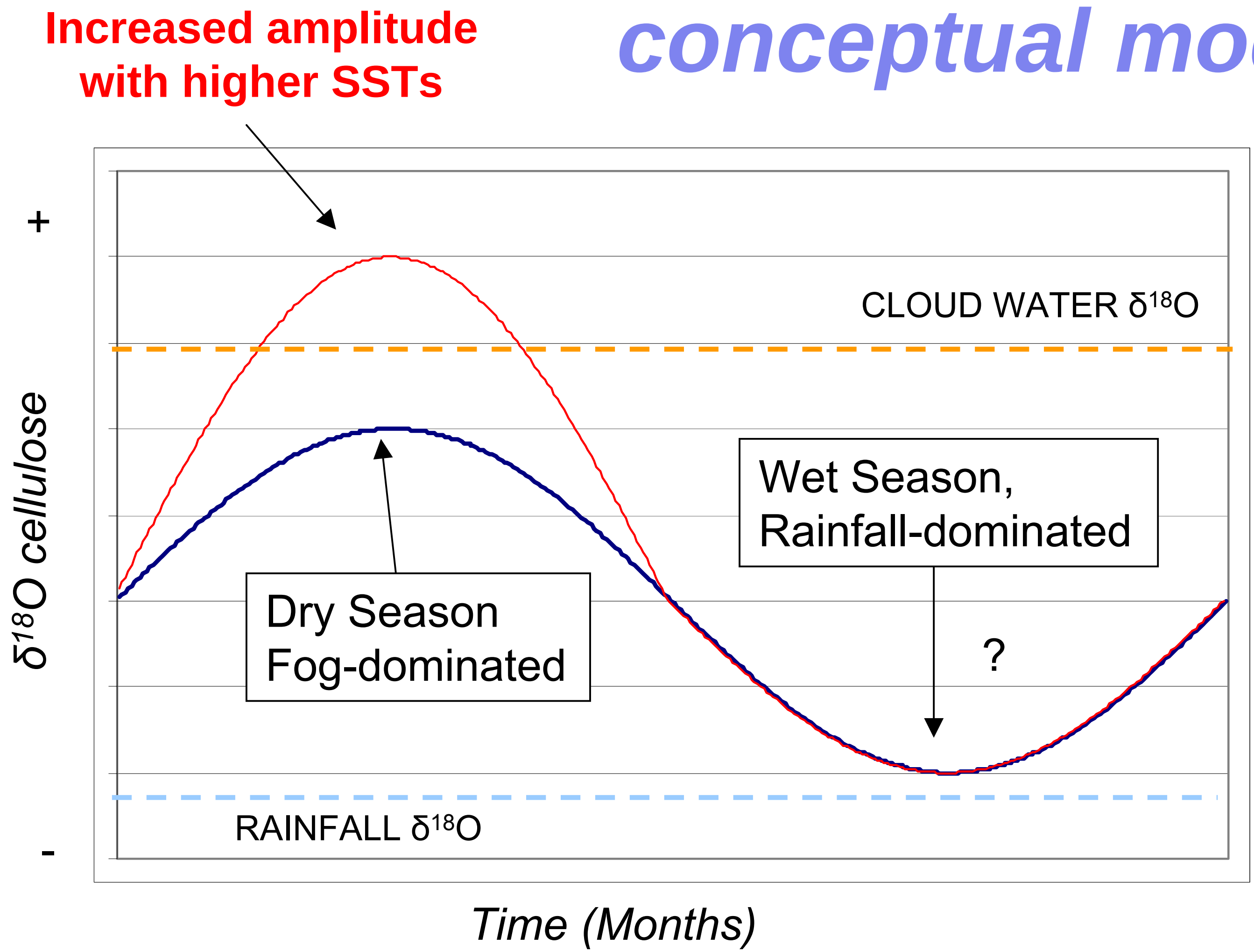
interannual variability



✓ Relative humidity decreases during the dry season at cloud forest elevations during warm ENSO events in Central America

Data source: Kalnay et al. [1997]

conceptual model



✓ In cloud forests, seasonal source water differences should dominate the yearly isotope cycle, while at interannual frequencies, periodic changes in relative humidity related to sea surface temperature variability (including ENSO events) should control isotope ratios in tree cellulose

Benefits from Cloud Forest Dendroclimatology

[1] **Potential for long records because of lower deforestation rates, slow growth rate of trees.**

[2] **More reliable ENSO signature? (Doesn't rely on circulation, not subject to proxy instability ?)**

[3] **Cloud forests sensitive to trends in global climate, including temperature/humidity changes as a consequence of natural or anthropogenic climate change.**

The Work Ahead

[1] Age model confirmation

[2] Replication

[3] Calibration, modeling, and chronology development

[4] Integration with mature proxies for climate field reconstruction